ISOKINETIC STRENGTH, IPSILATERAL AND BILATERAL RATIO OF PEAK MUSCLE TORQUE IN KNEE FLEXORS AND EXTENSORS IN ELITE YOUNG SOCCER PLAYERS

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Abstract

The aim of the study was to determine the profile of isokinetic strength of elite young soccer players (n = 12, mean age 17.5 ± 1.5 years). Assessment was performed on the isokinetic dynamometer. We evaluated: maximum peak muscle torque of knee extensors (PT_E) and flexors (PT_F) in both legs, ipsilateral ratio of muscle torque for both preferred and non-preferred extremities ($H:Q_P$ and $H:Q_N$, respectively), bilateral ratio between the exerted strength of knee extensors ($Q_P:Q_N$) and flexors ($H_P:H_N$). Strength parameters were obtained in the concentric contraction at angular velocities of 60, 120, 180, 240 and 300°·s^{-1}. PT_E and PT_F were significantly reduced with increasing movement velocity in both extremities ($p < 0.05$). At all velocities, PT_E was higher in the preferred extremity. A significant difference was at 60°·s^{-1} ($p < 0.05$). We did not find any significant difference in the level of strength between the preferred and non-preferred extremities in PT_F ($p > 0.05$). Increasing angular velocity had a significant effect on the size of ipsilateral H:Q ratio in both extremities ($p < 0.05$). The bilateral ratio of exerted strength in knee extensors, or flexors respectively, was not significantly different in the movement velocity ($p > 0.05$). At the highest velocity, a significant difference was found between the bilateral $Q_P:Q_N$ and $H_P:H_N$ ratios ($p < 0.05$). Precise determination and quantification of muscle strength imbalances is essential for determination of the fundamental level of organized and intentionally controlled training process and for early compensation of the found imbalances as prevention against potential injury of athletes.

Key words: *physical examination, resistance training, muscle strength, health, athletic injuries*

Introduction

Balance of physical abilities and their demonstration should be a part of the harmonious personality development of young athletes. The imbalance of muscle strength indicators has its own inner nature which is reflected in the external manifestation and in case of significant asymmetries it increases the probability of muscle injuries, or deterioration of sport performance. One essential function of the muscles is to protect and stabilize joints of the skeletal system. Hence, strength training is of importance also in preventing injuries as well as re-occurrence of injuries (Bangsbo et al., 2006). The study by Lehance et al. (2009), which examined muscle strength on isokinetic dynamometer in the preparatory period in elite soccer players (n = 57), showed that up to 56% of the players are at risk of muscle strength imbalances of knee flexors or extensors. The authors present a higher proportion of muscle strength imbalances in young soccer players in comparison to senior players. Out of total 24 professional French soccer players, 11 players declared totally 15 muscle injuries over a period of 24 months (Dauty et al., 2003). Four players reported muscle injury on both legs. Eight injuries were reported for the players' preferred extremities and seven for non-preferred extremities. In eight cases it was a moderate injury and in seven cases it was a severe muscle injury. The pressure on the players in terms of their participation in the game is huge in professional soccer. Croisier et al. (2006) monitored 617 professional players in the long term.

The authors suggest that up to 65% of players return to soccer after muscle injury despite continuous muscle problems. Croisier et al. (2005) indicate that the isokinetic strength assessment before the start of the season enables identification of strength indicators as predictors of possible muscle injury. Lehance et al. (2009) listed three important reasons that result in the diagnostics of strength abilities in athletes: to ascertain the absence of muscle strength imbalances between the extremities (or that imbalances are within the limits), to ensure that muscle strength is well balanced between the knee flexors and extensors and finally, that a soccer player with his level of strength abilities meets the standards (norms) according to his age and performance level. Testing on an isokinetic dynamometer enables the monitoring of strength manifestation in the concentric and eccentric contraction at a constant velocity, which allows intra- and interindividual comparisons when values are standardized. In concentric contraction it is possible to identify the weakest and strongest point in the course of the range of movement. In addition to monitoring of muscle strength of knee extensors (Q – quadriceps) and flexors (H – hamstring), which are determined by the level of maximum peak muscle torque (PT – peak torque), the strength ipsilateral ratio between hamstring (H) and quadriceps (Q) – H:Q ratio – is also examined for the needs of the assessment (Dauty et al., 2003; Li et al., 1996; Rosene et al., 2001). Hoffman (2006) states that PT is as reliable an indicator of muscle functionality for healthy, as it is for injured articulations. Monitoring of these movements of particular muscle groups around the articulation reflects its integrity and stability. The bilateral comparison of muscle strength of extremity muscle groups (e.g. the right vs. left knee flexor) or the comparison between the agonist and antagonist strength (e.g. knee flexor vs. extensor) may indicate potential weaknesses of the muscle system, which are predisposed to muscle injury (Baratta et al., 1988; Knapik et al., 1991; Lin et al., 2010). Knapik et al. (1991) state that the athletes with muscle strength imbalances higher than 15% at bilateral comparison of extremities had 2.6-times higher frequency of injuries when compared to athletes who had this difference lower than 15%. Dauty et al. (2003) indicate that in the case of muscle strength imbalances of knee flexors lower than 10% we can exclude muscle injury of the particular muscle groups, or after the injury the muscles have fully recovered and muscle strength can be fully produced. Fowler and Reilly (1993) state that 20% difference in the bilateral deficit of muscle strength in professional players is a predisposition to injury. The ratio of muscle strength of knee flexors and extensors (H:Q) for healthy people is in the range of 50 - 60%, while values for the soccer players range from 41 - 81%, depending on the angular velocity of the performed movement (Knapik and Ramos, 1980). Similarly, Kong and Burns (2010) present the range of 42 - 80% for healthy men and women. Hoffman et al. (1992) consider the ratio 6:10 as the accepted value of the H:Q ratio. Houweling et al. (2009) consider monitoring of the bilateral ratio of knee flexors strength (H:Q) at velocity $60°\cdot s^{-1}$ as the most valid indicator reflecting previous injury of this risk muscle group in soccer players. The aim of the study was to determine the profile of isokinetic muscle strength indicators of elite Czech young soccer players at different velocities of the performed movement and to identify muscle strength ratio between knee flexors and extensors and their bilateral muscle strength deficit.

Methods

Subjects

The screened sample was composed of young male soccer players of the highest junior league level (n = 12, mean age 17.5 ± 1.5 years, body height 174 ± 8.5 cm and body weight 75.6 ± 13.1 kg). The participants have played football for 11.5 years on average.

Assessment of strength indicators

From the perspective of sports training periodization, research was carried out at the end of the competition period. Assessment of muscle strength indicators was performed on the isokinetic dynamometer Cybex Humac Norm (Cybex NORM ®, Humac, CA, USA). The device is hydraulically directed and fully computer controlled in the continuous passive movement, isometric, isotonic and isokinetic concentric and eccentric mode. We evaluated the following parameters: maximum peak voluntary muscle torque of knee extensors (PT_E) and flexors (PT_F) in both legs, ipsilateral ratio of muscle torque for both preferred and non-preferred extremities ($H:Q_P$ and $H:Q_N$, respectively), bilateral ratio between the exerted strength of knee extensors ($Q_P:Q_N$) and flexors ($H_P:H_N$). Strength parameters were obtained in the concentric contraction at angular velocities of 60, 120, 180, 240 and $300°\cdot s^{-1}$. Reliability of PT at velocities 60, 120 and $180°\cdot s^{-1}$ was higher than 0.90 (Impelizzeri et al., 2008). Participants completed a short warm-up in the form of jogging (4 min) and dynamic half squats (2x15 repetitions) before the testing. The participant sat on the seat of an isokinetic dynamometer, which together with a dynamometer arm was ergonomically adjusted according to the manual and individually tailored to each participant so that the knee joint axis in the frontal plane was at the axis of the rotating dynamometer arm. For safety reasons, for each participant we adjusted individual range of motion, which ranged from 91° to 96° (the maximum extension was set as the „anatomic zero-0°"). The athlete's trunk and non-tested leg were fixed by means of fixing straps because of the isolation of the examined movement. The participant held the side handles of the device. The testing protocol consisted of 5 maximum attempts at knee extension followed by knee flexion sequentially from the lowest to the highest velocity. Maximal peak torque was used for statistical analyses. The procedure from the lowest velocity to the highest velocity has been standardized and recommended by Wilhite et al. (1992). Prior to each velocity, participants had 4 not tested attempts so that they could become familiar with the particular velocity. Between the tested velocities there was a break with passive rest of 1 minute in length (Rahnama et al., 2005). During the measurement, visual feedback and verbal stimulation were given. We also took into account the factor of gravitation of the isokinetic dynamometer arm and lower extremity segment, which was calculated by the dynamometer and compensated during the particular measurement.

Statistical analysis

Significant differences in the monitored parameters depending on the performed movement velocity were evaluated by the analysis of variance for repeated measurements (RM ANOVA), which compares the variance of within-groups effects. Determination of strength parameters significance between the individual velocities was then conducted using the multiple comparison of means (Bonferonni's *post-hoc* test). When the criterion of sphericity as one of the conditions of ANOVA, which was assessed by the Mauchly's test (χ^2), was not met, degrees of freedom were adjusted by means of Greenhous-Geisser's (GG) sphericity correction and then the statistical significance was assessed according to particular degrees of freedom. Rejection of the null hypothesis was assessed at the level of $p<0.05$. Effect size was assessed using the „Eta square" coefficient (η^2), which explains the proportion of variance of the monitored factor. Effect size was examined as follows: $\eta^2=0.20$–a small effect, $\eta^2=0.50$–medium effect and $\eta^2=0.80$–large effect (Cohen, 1992). The comparison of ipsilateral ratios (H:Q) between the preferred and non-preferred lower extremities or bilateral ratios (Q_P:Q_N and H_P:H_N) were carried out using the Student's t-test. Effect size between the means of the screened samples was assessed by means of Cohen's coefficient of effect size „d". It was calculated as the difference of the means of the compared parameters and divided by a „pooled" standard deviation (1) (Thomas and Nelson, 1996). The coefficient was assessed as follows: d = 0.20 – a small effect, d = 0.50 – medium effect and d = 0.80 – large effect (Cohen, 1992).

$$s_p = \sqrt{\frac{s_1^2(n_1-1)+s_2^2(n_2-1)}{n_1+n_2-2}} \qquad (1)$$

Statistical analysis was performed using SPSS 18.0.

Results

Muscle strength of knee extensors in the preferred extremity reached the highest value at the lowest velocity PT_{E60} = 3.54 ± 0.25 N·m·kg^{-1}. Exerted muscle strength significantly decreased with increasing velocity, ($F_{1.45;\ 15.93}$ = 520.11, $p < 0.05$, η^2 = 0.98). At the highest velocity (300°·s^{-1}), muscle strength achieved only 54% of muscle strength exerted at the lowest velocity. Analysis based on *post hoc* test showed a significantly different level of all mutually compared results of muscle strength exerted at different velocities of movement (Table 1). We also found significant changes in knee extensors strength in the non-preferred lower extremity depending on the performed movement velocity ($F_{4;\ 11}$ = 311.03, p < 0.05, η^2 = 0.97). The exerted muscle strength of knee extensors in the preferred leg was higher at all velocities. However, statistically significant difference and effect size were found only at the lowest velocity ($t_{(11)}$ = 3.05, $p < 0.05$, d = 0.75). Muscle strength of knee flexors was significantly decreased with increasing velocity in both the preferred and non-preferred legs ($F_{1.75;\ 19.23}$ = 74.82, $p < 0.05$, η^2 = 0.87 and $F_{2.37;\ 26.05}$ = 119.42, $p < 0.05$, η^2 = 0.92 respectively). Multiple comparisons of the means showed significant differences in peak muscle torque at all mutually compared velocities in both legs with the exception of the difference between muscle strength exerted at 120 vs. 180°·s^{-1} in the dominant lower extremity ($p > 0.05$) (Table 2). We have not found any statistically significant difference or effect size in the level of muscle strength between the preferred and non-preferred legs ($p > 0.05$, d < 0.40).

Table 1. Peak muscle torque of knee extensors (PT_E) in relative values (N·m·kg^{-1}) in the preferred and non-preferred lower extremities

Velocity (°·s^{-1})	Preferred extr. mean(SD)	Non-preferred extr. mean(SD)
60	3.54(.25)*,†,‡,§	3.34(.27)*,†,‡,§
120	2.90(.22)$^{*,‖,¶,\#,}$	2.79(.32)$^{*,‖,¶,\#,}$
180	2.46(.22)$^{†,‖,**,††}$	2.34(.38)$^{†,‖,**,††}$
240	2.15(.21)‡,¶,**,‡‡	2.09(.28)‡,¶,**,‡‡
300	1.91(.20)$^{§,\#,††,}$	1.85(.22)$^{§,\#,††,\ ‡‡}$
F	520.11	311.03
p	<.05	<.05
Eta	0.979	0.966

Velocity (°·s^{-1})	t	p	d
60	3.07	<.05	0.75
120	1.53	N.S.	0.39
180	1.96	N.S.	0.37
240	1.34	N.S.	0.25
300	1.53	N.S.	0.28

Legend: * – significant difference between velocities 60 and 120°·s^{-1}, † – significant difference between velocities 60 and 180°·s^{-1}, ‡ – significant difference between velocities 60 and 240°·s^{-1}, § – significant difference between velocities 60 and 300°·s^{-1}, ⍰ – significant difference between velocities 120 and 180°·s^{-1}, ¶ – significant difference between velocities 120 and 240°·s^{-1}, # – significant difference between velocities 120 and 300°·s^{-1}, ** – significant difference between velocities 180 and 240°·s^{-1}, †† – significant difference between velocities 180 and 300°·s^{-1}, ‡‡ – significant difference between velocities 240 and 300°·s^{-1}, N.S. – non-significant difference, d – Cohen's coefficient of effect size

Table 2. Peak muscle torque of knee flexors (PT_F) in relative values (N·m·kg^{-1}) in the preferred and non-preferred lower extremities

Velocity (°·s^{-1})	Preferred extremity mean (SD)	Non-preferred extremity
60	1.98(.21)*,†,‡,§	1.98(.21)*,†,‡,§
120	1.76(.19)$^{*,¶,\#,}$	1.83(.24)$^{*,⍰,¶,\#,}$
180	1.60(.24)†,**,††	1.61(.24)$^{†,⍰,**,††}$
240	1.39(.12)‡,¶,**,‡‡	1.44(.22)‡,¶,**,‡‡
300	1.26(.14)$^{§,\#,††,\ ‡‡}$	1.29(.22)$^{§,\#,††,\ ‡‡}$
F	74.82	119.42
p	<0.05	<0.05
Eta	.872	.916

Velocity (°·s^{-1})	t	p	d
60	.08	N.S.	0
120	-1.25	N.S.	.31
180	-.08	N.S.	.04
240	-.84	N.S.	.27
300	-.56	N.S.	.16

Legend: * – significant difference between velocities 60 and 120°·s^{-1}, † – significant difference between velocities 60 and 180°·s^{-1}, ‡ – significant difference between velocities 60 and 240°·s^{-1}, § – significant difference between velocities 60 and 300°·s^{-1}, ⍰ – significant difference between velocities 120 and 180°·s^{-1}, ¶ – significant difference between velocities 120 and 240°·s^{-1}, # – significant difference between velocities 120 and 300°·s^{-1}, ** – significant difference between velocities 180 and 240°·s^{-1}, †† – significant difference between velocities 180 and 300°·s^{-1}, ‡‡ – significant difference between velocities 240 and 300°·s^{-1}, N.S. – non-significant difference, d – Cohen's coefficient of effect size

Absolute values of peak muscle torque of knee extensors (PT_E) and flexors (PT_F) and its comparison between preferred and non-preferred leg are present in Figure 1 resp. Figure 2. Increasing angular velocity had a statistically significant effect on the unilateral relationship between the muscle strength exerted by flexors (hamstring) and extensors (quadriceps) in the preferred ($F_{1.41;15.52}$ = 9.271, $p < 0.05$, η^2 = 0.46) and non-preferred leg ($F_{1.88;20.69}$ = 10.378, p < 0.05, η^2 = 0.49) (Table 3). In case of the preferred lower extremity, *post hoc* analysis showed a significant difference between H_{60}:Q_{60} vs. H_{120}:Q_{120} and H_{60}:Q_{300}.

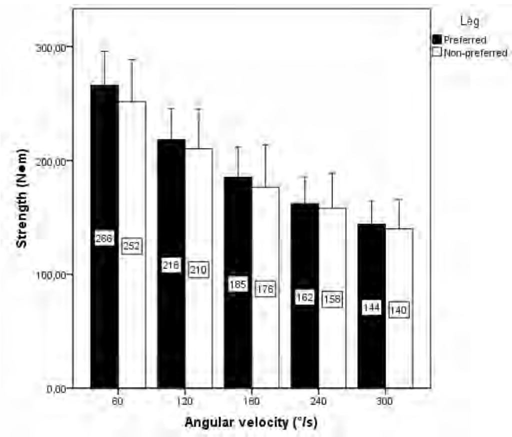

Figure 1. Comparisons of peak muscle torque of knee extensors (PT_E) in abs values (mean±SD)

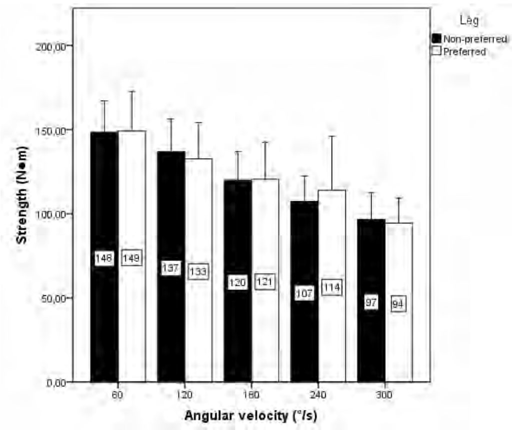

Figure 2. Comparisons of peak muscle torque of knee flexors (PT_F) in abs values (mean±SD)

The ratio H_{60}:Q_{60} in the non-preferred leg significantly differed from all other ratios found in the monitored velocities. We have not found any significant difference between the results of the preferred and non-preferred legs ($p > 0.05$). In terms of effect size, medium size effect was found at all velocities ($d = 0.38 - 0.64$), while higher coefficients were recorded at lower velocities (60 and 120°·s^{-1}). Bilateral ratio of muscle strength exerted by extensors or flexors was neither statistically nor effect size significant depending on the velocity of the performed movement ($F_{4;44} = 0.206$, $p > 0.05$, $\eta^2 = 0.18$ and $F_{4;44} = 2.305$, $p > 0.05$, $\eta^2 = 0.17$ respectively) (Table 4). Comparison of muscle strength balance between the ratio of muscle strength of extensors and flexors at different velocities showed a statistically significant and effect size significant difference at the maximum velocity ($t_{(11)} = -3.29$, $p < 0.05$, $d = 1.12$). Medium effect size of bilateral ratio between muscle strength of knee extensors and flexors was found at velocity of 240°·s^{-1} ($d = 0.62$). Differences in all other cases were not statistically significant.

Discussion

Knee extensor strength in the preferred leg, exerted on the isokinetic dynamometer by our participants, was $PT_{E60} = 3.54 \pm 0.25$ N·m·kg^{-1} at the lowest velocity.

Table 3. Ipsilateral ratio between peak muscle torque of knee flexors and extensors in the preferred and non-preferred lower extremities (H:Q)

Velocity (°·s^{-1})	Preferred extr. mean (SD)	Non-preferred extremity
60	55.75(4.83)*,§	59.42(6.83)*,†,‡,§
120	60.67(5.31)*	65.92(9.88)*
180	63.50(8.04)	68.17(12.41)†
240	64.42(8.37)	69.33(12.55)‡
300	66.08(8.82)*	70.83(14.73)§
F	9.271	10.378
P	<0.05	<0.05
Eta	.457	.485

Velocity	t	p	d
60	-1.46	N.S.	.60
120	-1.84	N.S.	.64
180	-1.34	N.S.	.43
240	-1.31	N.S.	.45
300	-1.09	N.S.	.38

Legend: *–significant difference between velocities 60 and 120°·s^{-1}, †–significant difference between velocities 60 and 180°·s^{-1}, ‡–significant difference between velocities 60 and 240°·s^{-1}, §–significant difference between velocities 60 and 300°·s^{-1}, N.S.–nonsignificant difference, d–Cohen's coefficient of effect size

Table 4 Bilateral ratio between peak muscle torque of knee extensors (Q_P:Q_N) and flexors (H_P:H_N)

Velocity (°·s^{-1})	Knee extension mean (SD)	Knee flexion mean (SD)
60	6.58(5.57)	7.67(4.83)
120	6.42(7.32)	7.58(5.52)$^{\#}$
180	6.25(6.08)	9.00(8.15)
240	6.17(5.17)	10.67(8.47)
300	5.58(5.44)	13.41(7.86)$^{\#}$
F	.206	.305
P	>0.05	>0.05
Eta	.18	.173

Velocity (°·s^{-1})	t	p	d
60	-.56	N.S.	.21
120	-.44	N.S.	.18
180	-1.11	N.S.	.37
240	-1.50	N.S.	.62
300	-3.29	<0.05	1.12

Legend: #–significant difference between velocities 120 and 300°·s^{-1}, N.S.–insignificant difference, d–Cohen's coefficient of effect size

Lower value $PT_{E60} = 3.06 \pm 0.44$ N·m·kg^{-1} in elite junior soccer players (I. Belgian league) was stated by Lehance et al. (2009). Juniors achieved higher muscle strength compared to professional senior players (2.98 ± 0.35 N·m·kg^{-1}). The same finding is presented in the study of Dauty et al. (2004) who state a difference of 16.5% between the professional senior and junior players. Kellis et al. (2001) indicate values of 2.92 ± 0.29 N·m·kg^{-1} in young Greek players. At a lower performance level, we observe a lower level of knee extensor strength. Newman et al. (2004) present values $PT_{E60} = 2.53 \pm 0.29$ N·m·kg^{-1} in 14 players of lower performance level. Torny-Chollet et al. (2000) state an even lower; value $PT_{E60} = 2.06 \pm 0.08$ N·m·kg^{-1} for the French amateur players (n = 21). The level of muscle strength declined with increasing velocity in both preferred and non-preferred lower extremities.

Generally, muscle strength, which the muscle is able to exert, decreases with increasing velocity of the movement in the concentric contraction. This relationship between muscle strength and speed of contraction is known as the Hill's curve (Hill, 1938). One of the explanations of this relationship is that the maximum time available for the contact between actin and myosin filaments reduces with increasing velocity of concentric activity (Huxley model), thus duration of the contact phase reduces in the overall cycle. Cross-bridges have to be re-released shortly after their connection without sufficient time to produce power, so the share of combined bridges in the muscle declines and the produced strength is lower (Wirth and Schmidtbleicher, 2007). Our participants exerted more muscle strength in knee extensors in the preferred leg compared to the non-preferred leg at each velocity. This finding is consistent with the results of other studies (Dauty and Potiron-Jose, 2004; Gür et al., 1999; Rahnama et al., 2003; Rahnama et al., 2005; Tourny-Chollet et al., 2000). However, some studies indicate examples when soccer players reached higher values in the non-preferred leg at least at one of the velocities (Kellis et al., 2001; Lehance et al., 2009). In our study, we found out both statistically and effect size significant difference between the muscle strength of extensors in both legs exerted at the lowest velocity. Rahnama et al. (2005) did not find any significant differences in knee extensor strength between the preferred and non-preferred legs at three different velocities (60, 120, 300 $°\cdot s^{-1}$) in elite soccer players. Similarly, muscle strength of knee flexors decreased with increasing velocity in both lower extremities ($p < 0.05$). *Post hoc* analysis showed significant differences at all velocities apart from the difference between velocities $120°\cdot s^{-1}$ vs. $180°\cdot s^{-1}$ in the preferred leg ($p > 0.05$). The difference between muscle strength at the highest and lowest velocity is 36.4% in the preferred leg and 34.9% in the non-preferred leg. We have not found significant differences in bilateral comparison of knee flexors strength. Rahnama et al. (2005) present significant differences in exerted strength between the preferred and non-preferred lower extremities at velocity $120°\cdot s^{-1}$. At higher velocities (120,180,240 and $300°\cdot s^{-1}$), our participants reached higher values in the non-preferred leg. The same result was found by Gür et al. (1999) in young players at velocities of 180,240 and $300°\cdot s^{-1}$. Lehance et al. (2009) also indicate higher muscle strength of knee flexors in the non-preferred extremity in professional senior players and elite junior players at velocity of $240°\cdot s^{-1}$. At lower velocity ($60°\cdot s^{-1}$), senior players achieved higher muscle strength in the preferred leg, while junior players in the non-preferred leg. Rahnama et al. (2005) state a significant difference in knee flexors strength of elite players at velocity of $120°\cdot s^{-1}$ in favor of the non-preferred leg, which exerted more muscle strength by 5.6% compared to the preferred leg. These findings are contrary to studies by Kellis et al. (2001), Tourny-Chollet et al. (2000), which found higher muscle strength of the preferred leg at higher velocities, as well.

Monitoring of ipsilateral ratio between muscle strength of knee flexors and extensors showed a significant effect of velocity on its level. The H:Q ratio raised with increasing angular velocity in both preferred and non-preferred extremities. This result is consistent with the results of the study by Kong and Burns (2010). The authors present a significantly different H:Q ratio at velocities of $60°\cdot s^{-1}$ vs. $180°\cdot s^{-1}$, but insignificant difference when comparing to velocities of $180°\cdot s^{-1}$ vs. $300°\cdot s^{-1}$. In our study, we have found out a significant difference of the monitored ratio in the preferred extremity between velocities of $60°\cdot s^{-1}$ vs.$120°\cdot s^{-1}$ or $300°\cdot s^{-1}$. The H:Q ratio in the non-preferred extremity at lower velocity significantly differed from the values obtained at other velocities. The bilateral comparison of H:Q ratio between the preferred and non-preferred legs did not show significant differences. The same result in professional players has been published by Rahnama et al. (2005). Our participants reached lower values of H:Q ratio for the preferred extremity compared with professional senior or elite junior players (Dauty et al., 2003; Lehance et al., 2009). Values of the non-preferred extremity were comparable with those of senior players and lower than those of junior players (Lehance et al., 2009). However, our participants achieved higher values in both extremities at all velocities compared to young players (Gür et al., 1999). Two players reached lower values of H:Q ratio than critical value for professional players (0.47) at velocity of $60°\cdot s^{-1}$,which means a risk muscle imbalance (Croisier et al., 2003). The bilateral ratio between muscle strength of knee extensors was not significantly different from the velocity of the performed concentric contraction. Its average level varied from 5.58 to 6.58%. In the individual evaluation, we recorded $Q_P:Q_N \geq 10\%$ in 6 players out of total of 60 measurements. One player reached values of $Q_P:Q_N \geq 20\%$, at all velocities which corresponds with a possible high risk of 15%. The bilateral ratio knee flexors strength was in the interval 7,58-13,41%. Croisier et al. (2003) indicate a risk bilateral difference between concentric muscle strength in professional players higher than 15%. The highest value was recorded at the maximum velocity ($300°\cdot s^{-1}$). At this velocity, statistically significant difference and effect size significance were proved. The key specific activities (shooting, acceleration, deceleration of movement, changes of direction, etc.) are performed especially at high velocity. We found a significant difference between $H_P:H_N$ ratio at velocities of $120°\cdot s^{-1}$ vs. $300°\cdot s^{-1}$. 10 players reached the ratio of $H_P:H_N \geq 10\%$. At the highest velocity ($300°\cdot s^{-1}$), we recorded values higher than 10% in eight players. This muscle imbalance may be a risk factor for injury, because players perform specific soccer movements at high speed (shooting, acceleration, deceleration, changes of direction, long distance passing, etc.). Rahnama et al. (2005) suggest that up to 68% of participants had muscle imbalance in extensors or flexors between the extremities higher than 10% in at least one of the measurements of muscle strength.

Conclusion

Measurements of isokinetic muscle strength provide an objective approach to diagnostics and simpler quantification of muscle strength and its parameters in soccer players. Nevertheless, there are many gaps in this area dealing with its manifestation in young players (Weir, 2000). Young elite players reached high values of muscle strength of knee extensors and flexors. The critical value of the ipsilateral H:Q ratio appeared in only two players. Muscle bilateral imbalances were found in at least one measurement in 50% of players at velocity of $60°\cdot s^{-1}$ and in 75% of players at velocity $300°\cdot s^{-1}$. In the training process (strength training especially), these findings should not be omitted but rather compensated by appropriate adaptation stimuli (exercises). Monitoring of isokinetic muscle strength indicators at the beginning of the preparatory period enables identification of possible muscle strength imbalances, which should be further reduced during the preparatory period. Screening examination of muscle strength imbalances may be thus a useful tool for prevention of muscle injuries in soccer players. Precise determination and quantification of muscle strength imbalances is essential for determination of the fundamental level of organized and intentionally controlled training process and for early compensation of the found imbalances.

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IZOKINETIČKA SNAGA, IPSILATERALNI I BILATERALNI ODNOS MAKSIMUMA MIŠIĆNOG OBRTNOG MOMENTA FLEKSORA I EKSTENZORA KOLJENA MLADIH ELITNIH NOGOMETAŠA

Sažetak

Cilj ovog istraživanja je bio utvrđivanje profila izokinetičke snage elitnih mladih nogometaša (n = 12, ar. sredina 17.5 ± 1.5 godina). Procjena je izvedena na izokinetičkom dinamometru. Evaluirano je: maksimalni vrh mišićnog momenta sile ekstenzora koljena (PT_E) i fleksora (PT_F) obje noge, ipsilateralni odnos mišićnog momenta sile bolje i slabije noge ($H:Q_P$ and $H:Q_N$, respektivno), bilateralni odnos između naprezanja u snazi ekstenzora koljena ($Q_P:Q_N$) i fleksora ($H_P:H_N$). Parametri snage su dobiveni u koncentričnoj kontrakciji kod kutnih brzina od 60, 120, 180, 240 and 300°·s^{-1}. PT_E i PT_F značajno su reducirani povećanim momentom brzine oba ekstremiteta ($p < 0.05$). Kod svih brzina, PT_E je bio viši kod boljeg ekstremiteta. Značajna razlika bila je kod 60°·s^{-1} ($p < 0.05$). Nisu pronađene nikakve značajne razlike u razini snage između boljeg i slabijeg ekstremiteta kod PT_F ($p > 0.05$). Povećanje kutne brzine imalo je značajan učinak na veličinu ipsilateralnog H:Q odnosa kod oba ekstremiteta ($p < 0.05$). Bilateralni odnos snage naprezanja ekstensora koljena, ili fleksora respektivno, nije bio značajno različit u brzini kretanja ($p > 0.05$). Pri najvećoj brzini, značajna razlika je pronađena između bilateralnih $Q_P:Q_N$ i $H_P:H_N$ odnosa ($p < 0.05$). Precizno određenje i kvantifikacija neravnoteže mišićne sile je esencijalna za određivanje temeljne razine organiziranog i namjerno upravljanog trenažnog procesa kao i za ranu kompenzaciju eventualne neravnoteže kao prevencije potencijalnih povreda sportaša.

Ključne riječi: *fizičko ispitivanje, trening izdržljivosti, snaga muskulature, zdravlje, sportske povrede*

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